# Europium

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| **Symbol:** | **Eu** |
| **Atomic Number:** *(protons in nucleus)* | **63** |
| **Atomic Weight:** *(naturally occurring)* | **152** |

***What Is It?*** Europium is a silvery-white metal. It is the softest, least dense, and most volatile member of the lanthanide series, and it ignites in air at high temperatures (150 to 180°C). In nature, europium occurs as two stable isotopes. (Isotopes are different forms of an element that have the same number of protons in the nucleus but a different number of neutrons.) Europium-153 accounts for 52% of natural europium, and europium-151 makes up the remaining 48%.

Of the fourteen major radioactive isotopes, only four have half-lives long enough to warrant potential concern. The half-lives of all other europium isotopes are less than four months. Of these four longer-lived isotopes, three (europium-152, europium-154, and europium-155) are produced by the fissioning of uranium and plutonium and are present at Department of Energy (DOE) environmental management sites such as Hanford. These three isotopes have half-lives ranging from 5 to 13 years, and they decay by emitting a beta particle. A fraction (28%) of the europium-152 decays is by electron capture. A significant amount of energy in the form of gamma rays accompanies the decays of europium-152 and europium-154.

**Radioactive Properties of Key Europium Isotopes**

| Isotope | Half-Life *(yr)* | Specific Activity *(Ci/g)* | Decay Mode | Radiation Energy *(MeV)* | | |
|---|---|---|---|---|---|---|
| | | | | Alpha *(α)* | Beta *(β)* | Gamma *(γ)* |
| **Eu-150** | 34 | 70 | EC | - | 0.044 | 1.5 |
| **Eu-152** | 13 | 180 | β, EC | - | 0.14 | 1.2 |
| **Eu-154** | 8.8 | 270 | β | - | 0.29 | 1.2 |
| **Eu-155** | 5.0 | 470 | β | - | 0.063 | 0.061 |

*EC = electron capture, Ci = curie, g = gram, and MeV = million electron volts; a dash means the entry is not applicable. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for an explanation of terms and interpretation of radiation energies.) Europium-152 decays both by emitting a beta particle (28%) and electron capture (72%). A second isotope of europium-150 having a half-life of 13 hours also exists. Values are given to two significant figures.*

***Where Does It Come From?*** Europium is found in a variety of ores, primarily bastnasite, monazite, and xenotime. These ores contain different mixes of rare earth metals, which are the elements from lanthanum through lutetium in the periodic table. Europium generally makes up less than 0.2% of this mixture. China currently produces the vast majority of the rare earth metals, totaling about 70,000 metric tons (MT) annually. The United States comes in a distant second, producing around 5,000 MT annually, and europium makes up only a small fraction of this amount.

While europium-152, europium-154, and europium-155 are produced primarily as fission products, europium-152 can also be produced by neutron activation of nuclear reactor control rods. When a fissile nuclide such as an atom of uranium-235 fissions, it generally splits asymmetrically into two large fragments – which can include the three europium isotopes – and two or three neutrons. The fission yield of europium-155 is about 0.03% while the yield of the other two isotopes is much lower. That is, about 3 atoms of europium-155 are produced per 10,000 fissions. In order to control this fission reaction, isotopes that can absorb excess neutrons are used in nuclear reactor control rods. Because europium-151 is a very good neutron absorber, it is often used in these control rods. Neutron activation of this stable isotope produces europium-152.

***How Is It Used?*** The primary use of europium is in nuclear reactor control rods, because of its effectiveness in absorbing neutrons. Other uses have been limited because it is rare and thus very expensive. Europium-doped plastics have been used as laser materials, and europium oxide serves as a phosphor activator. For example, europium has been used to activate yttrium vanadate for its use in the red phosphors of color television tubes.

***What's in the Environment?*** Europium is present in the earth's crust at a concentration of about 1.8 milligrams per kilogram (mg/kg), while its concentration in seawater is about 0.00013 micrograms per liter. Trace amounts of europium-152, europium-154, and europium-155 are present in soil around the globe from radioactive fallout. It can also be present at certain nuclear facilities, such as reactors and facilities that process spent nuclear fuel. At the Hanford Site, the highest concentrations of europium are in areas that contain waste from the processing of irradiated fuel, such as the tanks in the central portion of the site. Europium is generally one of the more immobile radioactive metals in the environment.

It preferentially adheres fairly tightly to soil, and the concentration associated with soil particles is estimated to be about 240 times higher than in interstitial water (the water in the pore space between soil particles). Thus, europium is generally not a major contaminant in groundwater at DOE sites.

***What Happens to It in the Body?*** Europium can be taken into the body by eating food, drinking water, or breathing air. Gastrointestinal absorption from food or water is the principal source of internally deposited europium in the general population. Europium is not well absorbed into the body after intake, with only about 0.05% of the amount ingested being absorbed into the bloodstream through the digestive tract. Of the europium that reaches the blood, 40% is deposited in the liver, and another 40% is deposited on the surface of the bone, where it can irradiate the bone-forming cells; this deposited europium is retained in the body with a biological half-life of almost 10 years (3,500 days); an additional 6% of the absorbed europium is deposited in the kidneys, where it is retained with a short biological half-life of 10 days (per simplified models that do not reflect intermediate redistribution). The remainder of the absorbed europium is excreted.

***What Are the Primary Health Effects?*** Europium poses an external as well as an internal health hazard. The strong gamma radiation associated with europium-152 and europium-154 makes external exposure to these two isotopes a concern. While in the body, europium poses a health hazard from both the beta particles and gamma rays, and the main health concern is associated with the increased likelihood of inducing cancer in the liver and bone.

***What Is the Risk?*** Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including europium *(see box at right)*. While the coefficients for ingestion are somewhat lower than for inhalation, ingestion is generally the most common means of entry into the body. Similar to other radionuclides, the risk coefficients for tap water are about 70% of those for dietary ingestion.

In addition to the risks from internal exposure, a risk from external gamma exposure is associated with europium-152 and europium-154. If it is assumed that 100,000 people were continuously exposed to a thick layer of soil with an initial average concentration of 1 picocurie (pCi)/g, then the number of fatal cancers estimated for these 100,000 people is 7 for exposure to europium-152 and 5 for exposure to europium-154. (This can be compared to the 25,000 people from this group who would be predicted to die of cancer from all other causes per the U.S. average.)

### *Radiological Risk Coefficients*

*This table provides selected risk coefficients for inhalation and ingestion. Maximum values are given for inhalation since no default absorption types were provided, and dietary values were used for ingestion. Risks are for lifetime cancer mortality per unit intake (pCi), averaged over all ages and both genders ($10^{-9}$ is a billionth, and $10^{-12}$ is a trillionth). Other values, including for morbidity, are also available.*

| Isotope | Lifetime Cancer Mortality Risk | |
|---|---|---|
| | Inhalation (per $pCi^{-1}$) | Ingestion (per $pCi^{-1}$) |
| Europium-150 | $2.1 \times 10^{-10}$ | $3.6 \times 10^{-12}$ |
| Europium-152 | $1.5 \times 10^{-10}$ | $5.0 \times 10^{-12}$ |
| Europium-154 | $1.7 \times 10^{-10}$ | $8.5 \times 10^{-12}$ |
| Europium-155 | $1.7 \times 10^{-11}$ | $1.6 \times 10^{-12}$ |

*For more information, see the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients and the accompanying Table 1.*